

TRANS-PLANETARY SUBWAY SYSTEMS -- A BURGEONING CAPABILITY

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February 1978

P-6092

The Rand Paper Series

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The Rand Corporation
Santa Monica, California 90406

TRANS-PLANETARY SUBWAY SYSTEMS -- A BURGEONING CAPABILITY

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Introduction

My talk today is on a subject that affects you all -- transportation. I will describe a subway concept called "Planetran." Planetran is not an ordinary subway system, but rather one moving at thousands of mph. As seen in Figure 1, its cars travel in underground evacuated tubes and are electromagnetically supported and propelled. Cars float on these electromagnetic fields just as a surfboard rides ocean waves (Figure 2).

Planetran can cross the United States in an hour or so. It can be extended to a worldwide network using under-ocean tunnels to connect continents. It is designed to interface with existing subway and local transit systems in the same stations. Safe, convenient, low-cost, efficient, and non-polluting service is offered. Planetran's tunnel complex also can house utility transmission and auxiliary freight-carrying systems.

The Planetran concept was put forward some years ago in a search for transport methods operating at speeds comparable with aircraft. A high-speed train by conventional standards is one like the Japanese "Kodama" which operates at speeds in excess of 100 mph. Experimental surface transit vehicles using magnetic levitation (MAGLEV) have attained 300 mph. However, even at these speeds terrestrial systems cannot compete with aircraft over long distances.

Transit Speeds

Planetran can readily exceed conventional aircraft speeds and even those of future hypersonic planes (Figure 3). Further, Planetran does not need to climb to high altitudes to find favorable atmospheric conditions for high speed. The fastest Planetran case examined -- coast-to-coast in 21 minutes -- assumes one "g" propulsion. A maximum of 14,000 mph is reached. Cars are continuously accelerated to midpoint,

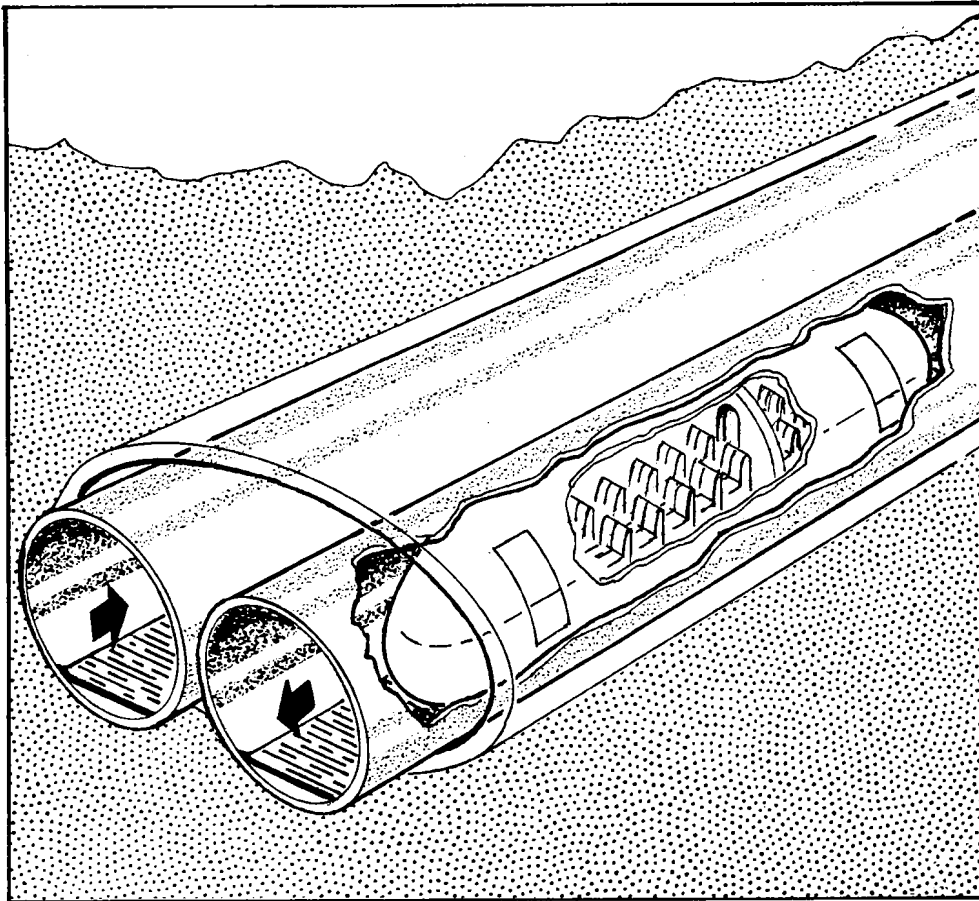


Fig. 1 — 2-way Planetran System

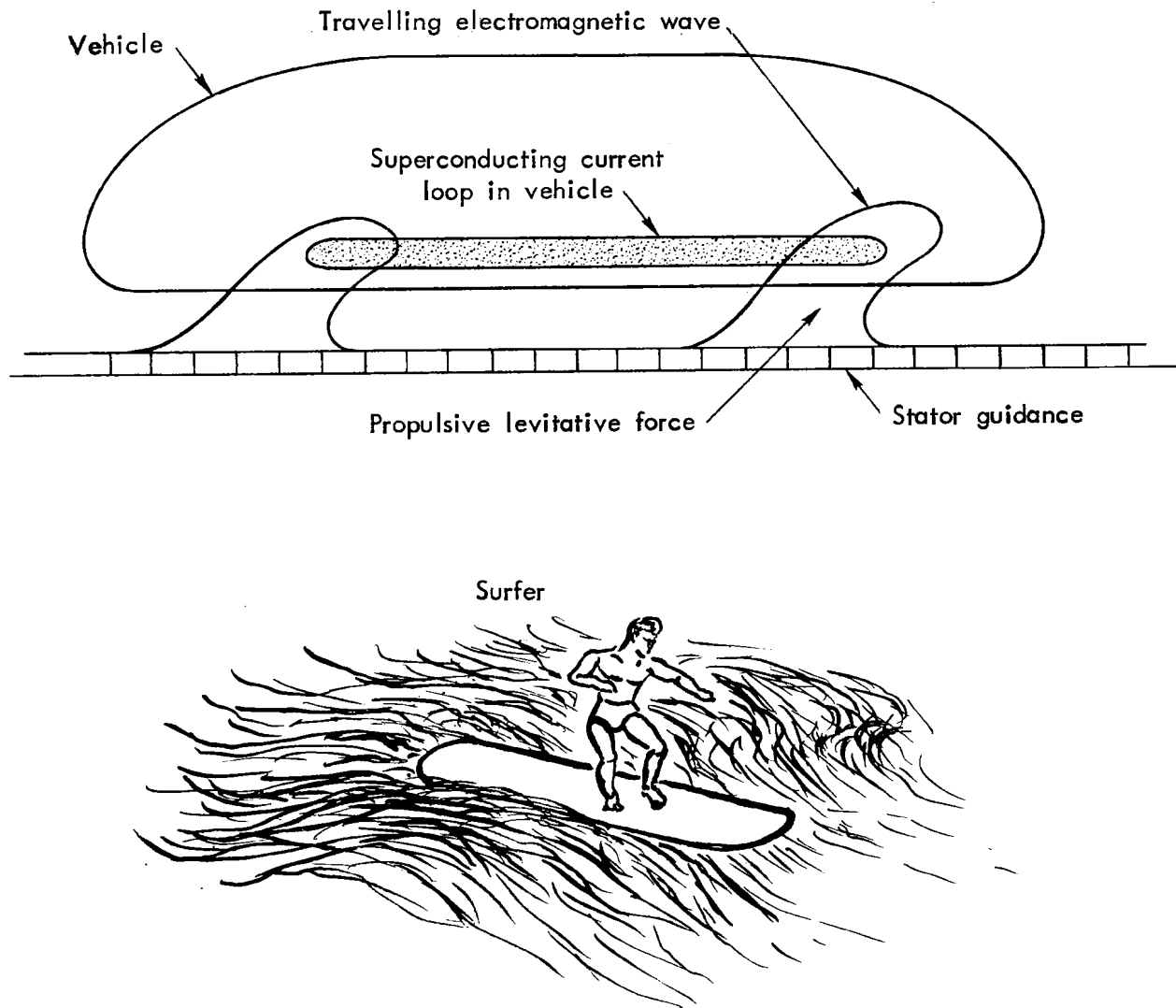
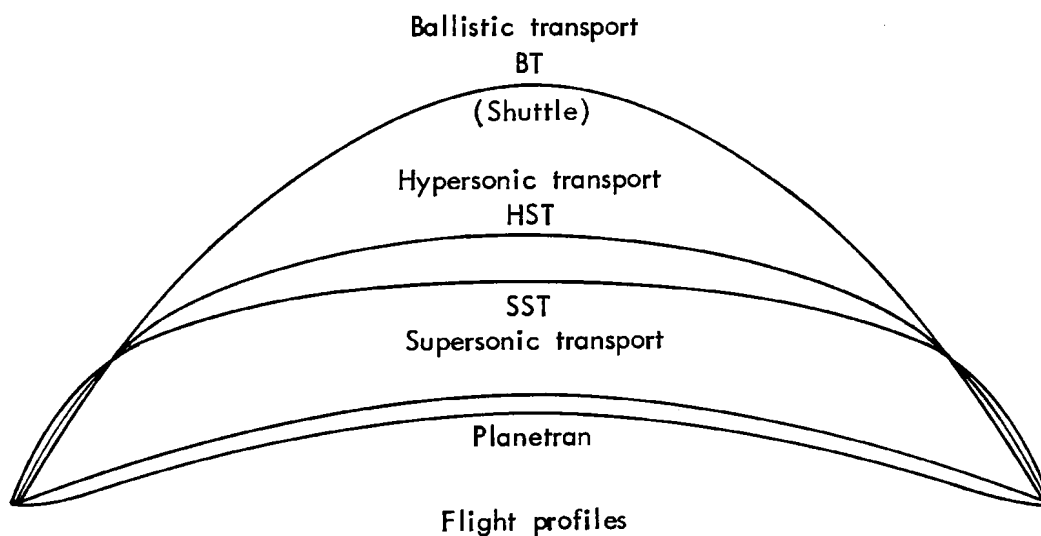


Fig. 2



Transport	Time minutes			Acceleration
	Climbing	Cruise	Total	
Planetran (non-stop)	0	21	21	1 g continuous
Planetran (one-stop)	0	54	54	1/3 g continuous
Supersonic (improved)	20	72	92	1/6 g
Hypersonic	30	49	79	1/2 g
Ballistic	6	33	39	.3 to 3 g

Fig. 3— Comparison chart of Planetran, Supersonic, Hypersonic and Ballistic transport

and continuously decelerated from there. With properly positioned seats, passengers feel these propulsive forces as additional weight. At the start and finish in this case passengers feel 40% heavier. Near midpoint, they feel only a few percent heavier. This is because centrifugal forces are compensating for their own weight so they are feeling mostly the one g thrust forces (Figure 4).

Experimental facilities are not yet available to determine passenger response to such accelerations and limits for comfort acceptability. Thus we don't know how realistic this 21-minute case is. It should be noted, however, that airborne systems might need 21 minutes just to get to and from high altitude. Further, aircraft do not have Planetran's prospects for terminating in a downtown subway station with one minute or less headways (time spacings between cars).

For economic and other reasons initial phases of Planetran will not include a non-stop coast-to-coast case. Our early work assumed stops at Chicago and Amarillo. Studies of population distribution led us recently to substitute Dallas for Amarillo at a 10% increase in total route length. Very recently we have modified the route assumptions still further as presented in Figure 5. This shows a primary Los Angeles-New York route with one stop at Dallas backed up by an additional route from Dallas to New York via Chicago.

Figure 6 is a summary of transcontinental transit times (and maximum velocities) for continuous accelerations/decelerations of one g and $1/3$ g and for non-stop, one-stop (Dallas), and two-stop cases. Note that the one-stop case increases our (one-g) trans-U.S. 21-minute time to 31.5 minutes. At $1/3$ g this one-stop time is further increased to 54.5 minutes. Maximum speed for this latter case is 6000 mph.

It may be more desirable for passenger comfort to have higher accelerations at the start and finish of each link with no forces in between rather than the steady forces of the above case. At 0.6 g thrust for 4-5 minutes at each end of the links we find a case yielding the same transit times as above. For $2/3$ of the trip no thrusts are felt. During the remainder passengers feel $1/6$ th heavier.

This last case reaches only 3600 mph and uses 0.6 of the energy of the constant $1/3$ g case. Obviously a critical consideration is in the

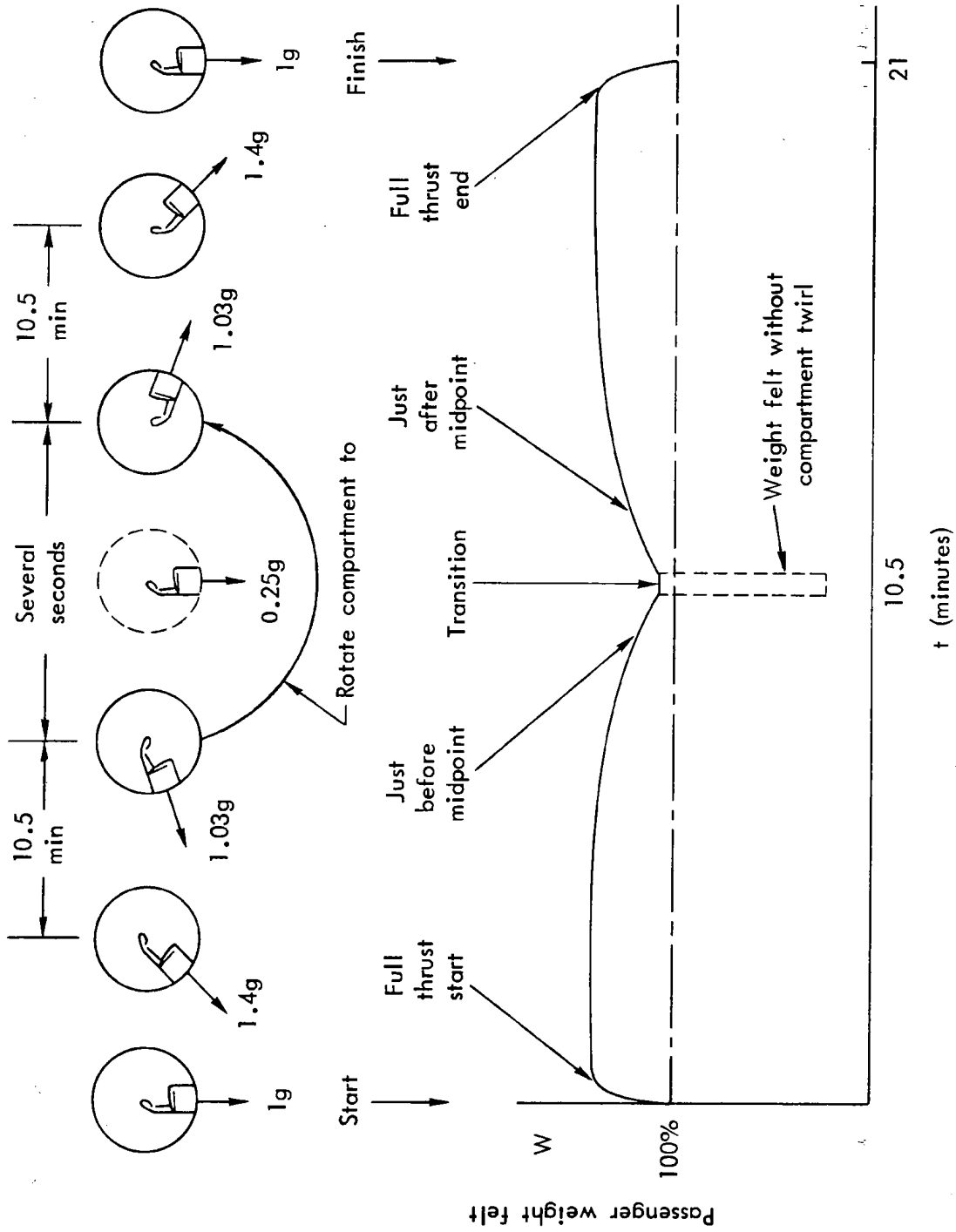


Fig. 4—Acceleration of passenger in gimbaled compartment in 21-minute transcontinental transit in Planetran

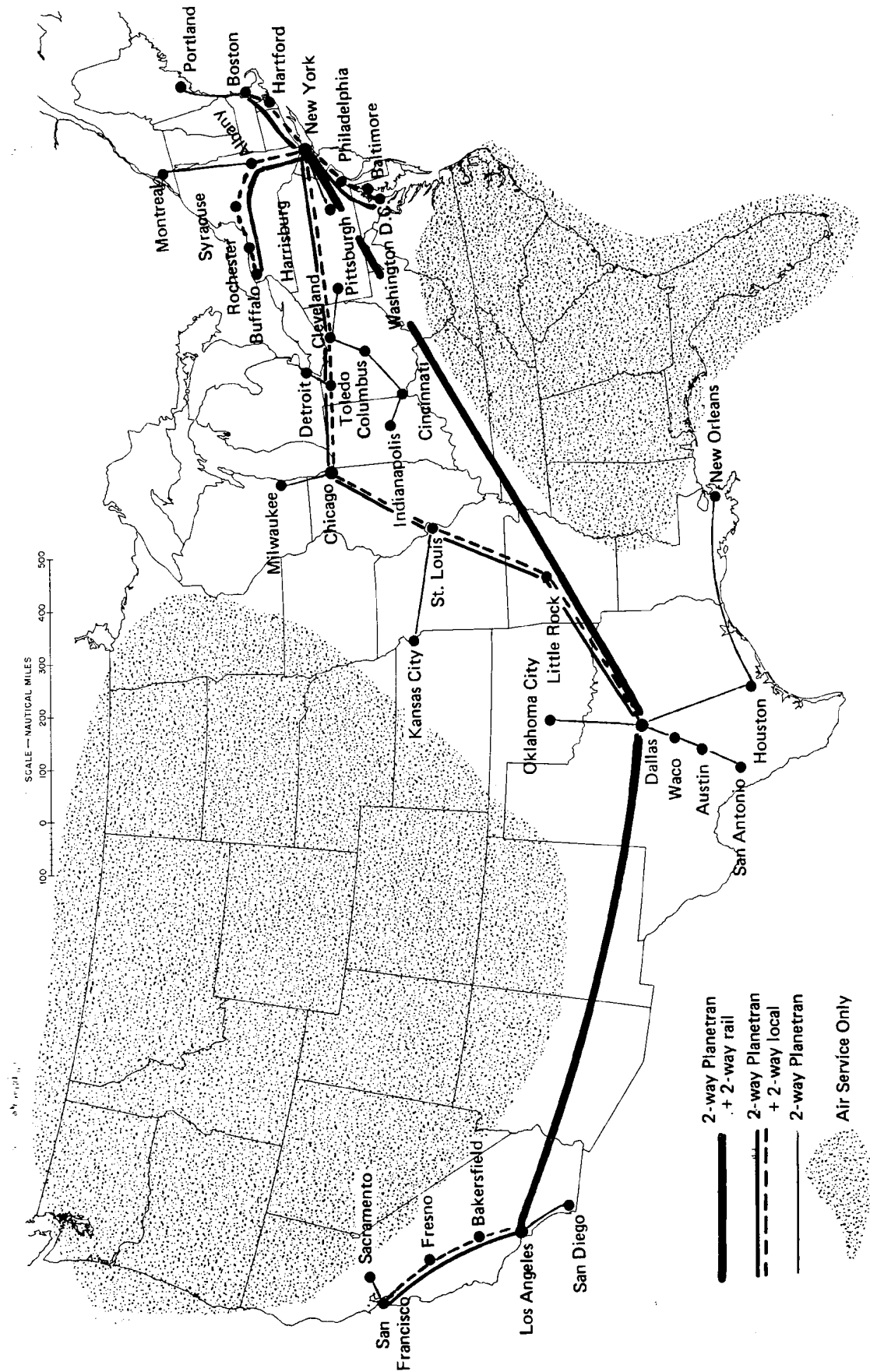


Fig. 5— Early Planetran U.S. route system

Cases	<u>One g</u> ($\Delta W = 40\%$)*	<u>1/3 g</u> ($\Delta W = 5\%$)
	Minutes (MPH)	Minutes (MPH)
<u>Non-stop</u> 2450 miles	21 (14000)	36.5 (8300)
<u>One-stop (Dallas)</u> 2720 miles	31.5 (10400)	54.5 (6000)
<u>Two-stop</u> 3010 miles	40 (10400)	70 (6000)

* ΔW is additional body weight increment felt by passengers

Fig.6— Planetran transit times (and maximum velocities) for Los Angeles to New York with and without stops at Dallas and Chicago

Continuous acceleration/deceleration

tradeoff of transit time for passenger comfort and the type of acceleration schedule. A schedule like the last case with higher acceleration at link ends but with a tapering to smaller thrusts in the middle might be the best choice (Figure 7).

The Route System

Planetran is designed so that all cars follow the same precise acceleration schedule. Thus a New York-bound car from California must pause for a few seconds at Dallas. A car only going from Los Angeles to Dallas is quickly replaced at Dallas by one going to Chicago, or New York -- or Boston.

Figure 5 depicts possible U.S. Planetran routes. Vehicles from feeder links are phased into the ends and two interchange points of the main coast-to-coast channel. Intermediate terminals at Dallas and Chicago are shown.

In our earlier work we postulated use of adjoining but separate tunnels for various users. Presently we're exploring shared usage of single tunnels as a means for substantial system cost savings. As a consequence, three different types of links are designated in Figure 5 and illustrated in Figure 8. The principal cross-country route (shown in heavy lines) includes both two-way Planetran and two-way Fast Rail Service (FRS). Figure 8a represents a tunnel cross-section and shows relative position of Planetran tubes and FRS rails. The double lines for Dallas-Chicago and Chicago-New York plus a number of key feeder lines represent a four-tube per tunnel configuration -- two of the tubes for two-way Planetran non-stop service and the other two tubes for local Planetran service. (One or both of the local Planetran tubes may be replaced by FRS rails with somewhat reduced size cars.) The dotted lines are for local Planetran feeders with two tubes/tunnel.

It should be realized that the particular routes chosen were selected for illustrative purposes only and do not represent a rigorous investigation of the best Planetran configuration. A search for optimal routing presents an interesting and challenging problem and will require an extensive bank of physiographic information.

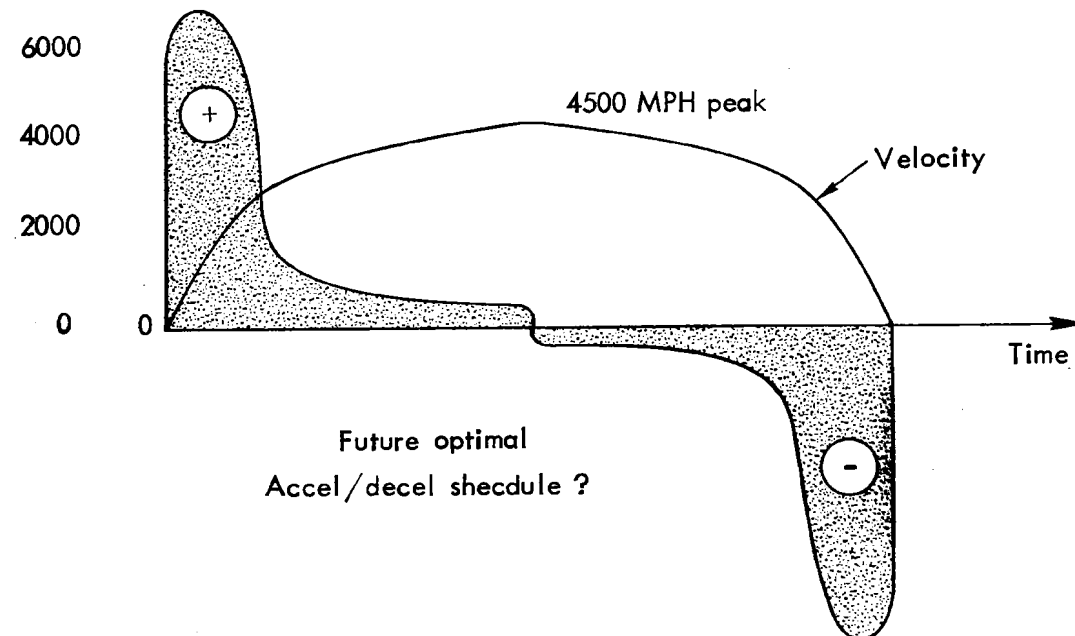
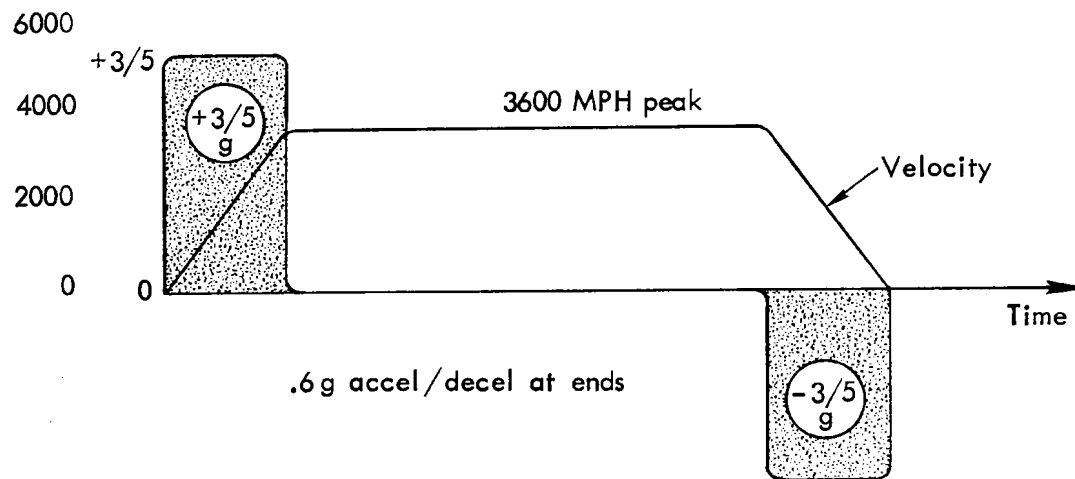
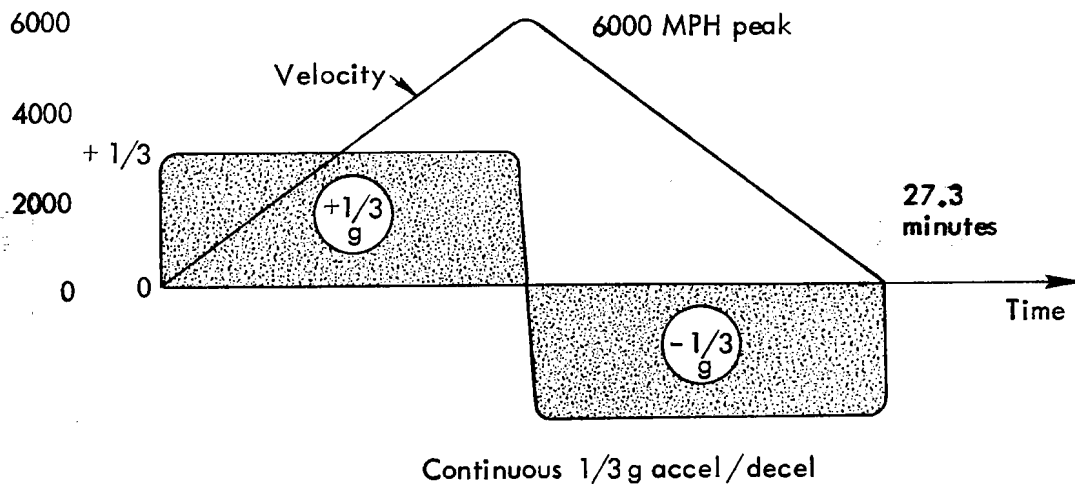


Fig. 7—Comparative acceleration schedules Dallas to N.Y. or L.A. links

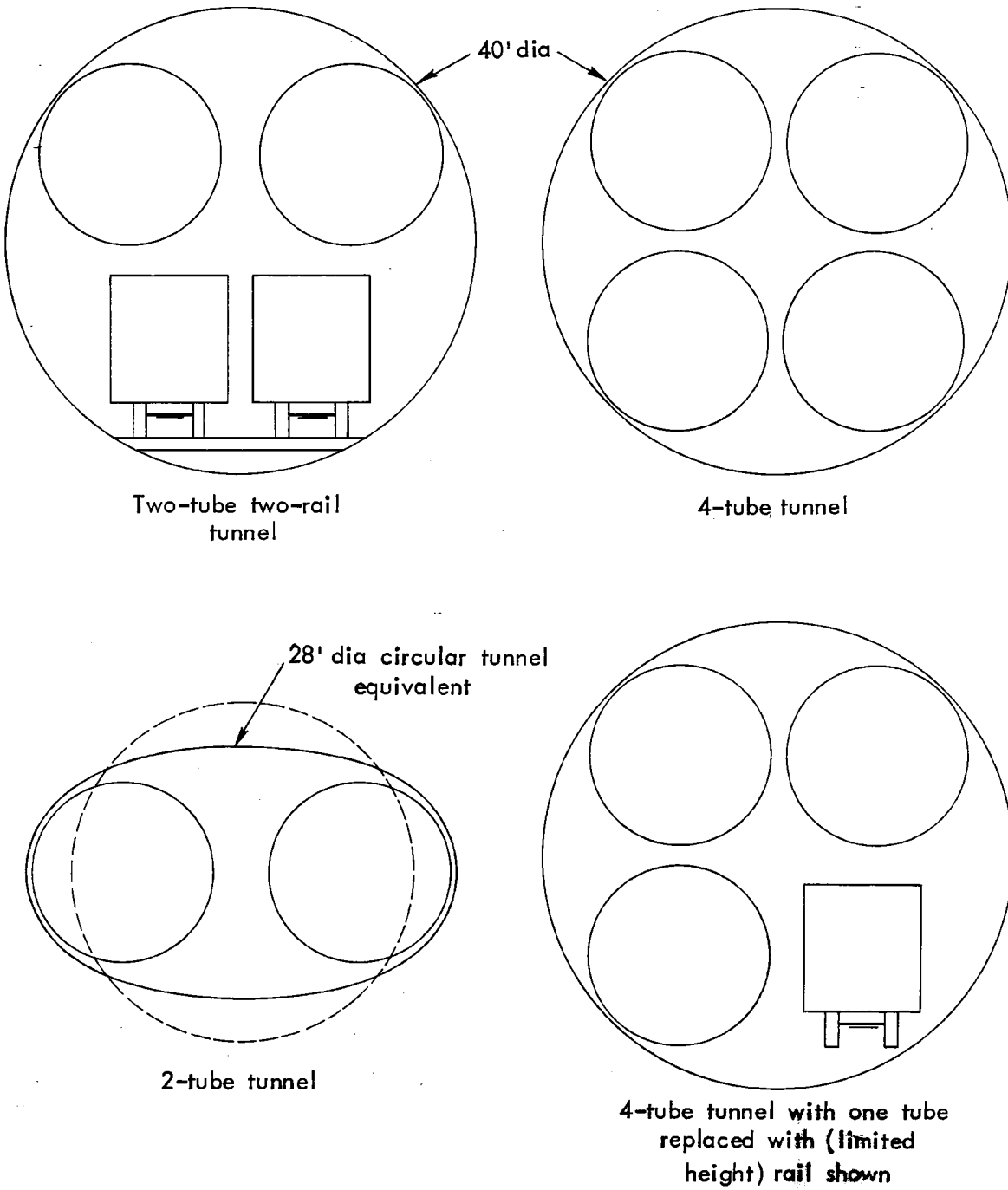


Fig. 8—Tunnel arrangements assumed for planetron

Subsidiary lines enter the four main terminals from such places as San Francisco, Boston, and Detroit. The best routing for any particular trip would be shown on a computer display, continuously updated, which would indicate whether a through tubetrain or a combination of shorter hops would be the faster mode. Some of the through cars will be dedicated for National Security use or for a more expensive class of service. Through cars can operate on both central corridor and principal feeder lines so that a traveler can go from, say, San Diego to Buffalo or Detroit to New Orleans in the same car. Automatic ticketing machines in each terminal will simultaneously make appropriate space reservations for routings requiring intermediate transfers (Figure 9).

Cheaper fares will apply for off-peak hours. Cars lacking a full passenger load will be ballasted with priority freight.

Future U.S. transportation approaches are assumed to be extensions of present ones, including subways for local mass transit and automobiles for the bulk of intracity and intercity travel. Autos have performed over 90 percent of the travel between cities over the last three decades; although it is not predicted that this will significantly decrease, it is expected that there will be improvements in automotive vehicles to make them safer and environmentally acceptable, that there will be improved mass transit (with added "people-mover" systems) to handle local traffic, and that much better interfaces will be established between these modes of travel. Planetran is designed to connect directly with local systems. It is visualized that a passenger steps off a subway (or a people-mover from an auto parking facility) and gets on a Planetran car in the same terminal.

Planetran's system will connect with airports to provide the best overall transportation service. Although it is expected that severe encroachment on airline service will occur along Planetran's corridor areas, air traffic volume may actually be greatly increased to regions in the U.S. (and abroad) not served by Planetran. It is expected that both short- and long-haul aircraft modes would be continued into the future.

A traveler planning to go from Boston to the Caribbean may, for example, find cases where it is more convenient to travel Planetran via Dallas and Houston to New Orleans and fly from there.

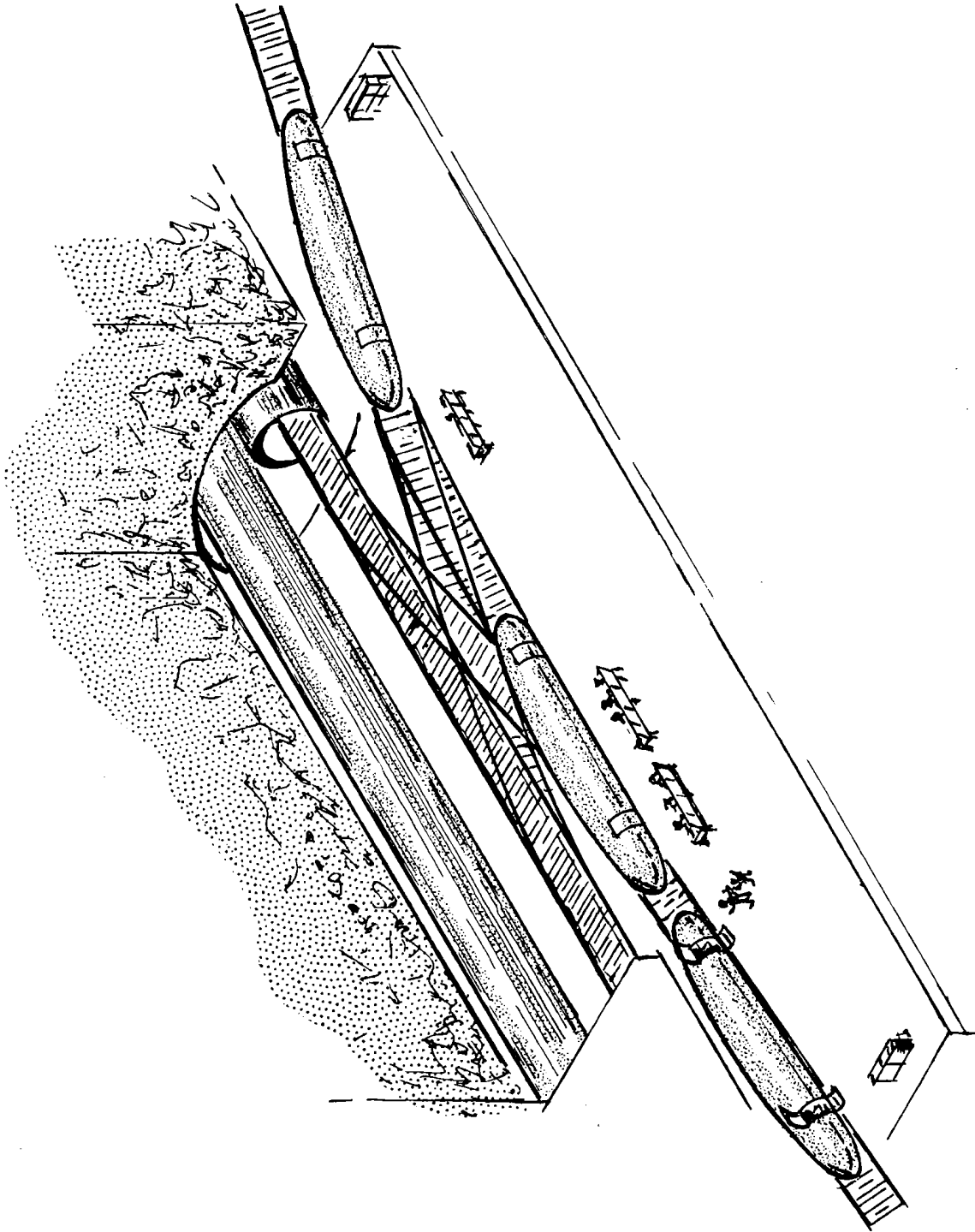


Fig. 9— Planetran terminal

Underground Requirements

Planetran's evacuated channels can be placed aboveground and there may be special instances where this is appropriate. However, to provide a truly high-speed system we must go underground. We must place tunnels at least several hundred feet down to find solid rock formations. In some instances depths of a mile or so will be necessary when tunneling under mountains or ocean straits.

High-speed sections of Planetran require large route curvatures while with FRS we must avoid all but the gentlest of grades ($\geq 1/2\%$). This places severe constraints on route siting, particularly in mountainous areas. Although one-mile depths are possible permitting simply tunneling under rugged areas, extensive lengths far underground are not desirable. It is believed (although not assured) that routes can be found that meet the above objectives. Figure 10 illustrates typical choices to be made.

Tunnels will represent a major problem area for Planetran -- *and most of its cost*. The best system compromise thus is one that minimizes tunnel cost at the expense of other system components. We have already discussed placing several tubes in one tunnel (Figure 8). Planetran vehicles should be long and narrow to minimize tube size, suggesting an actual train of connected cars. Smaller tubes are advantageous for reasons of vacuum pumping, tunnel packing, and use of smaller acceleration hardware. (For this latter, a train of several cars will require several cycles of acceleration compared to one cycle for a single car).

The route configuration of Figure 5 employs 2720 miles of tunnels on principal corridor (2 tubes + 2 rail tracks) and a like length for the 4-tube tunnel arrangement for Dallas-Chicago-New York links plus major feeder lines. This totals out to 5440 miles of large tunnels assumed to be 40 ft in diameter and 2405 miles of two-tube tunnels elliptical in shape (as shown in Figure 8) but equivalent in area to a 28-ft diameter circular tunnel. Connecting local transit links to nearby cities will bring Planetran service to perhaps 80% of the U.S. population. Such a tunnel system without terminal facilities and internal tubes could cost \$100 billion at today's prices (conservatively taking as a reference 10-meter tunnels at \$10 million/mile).

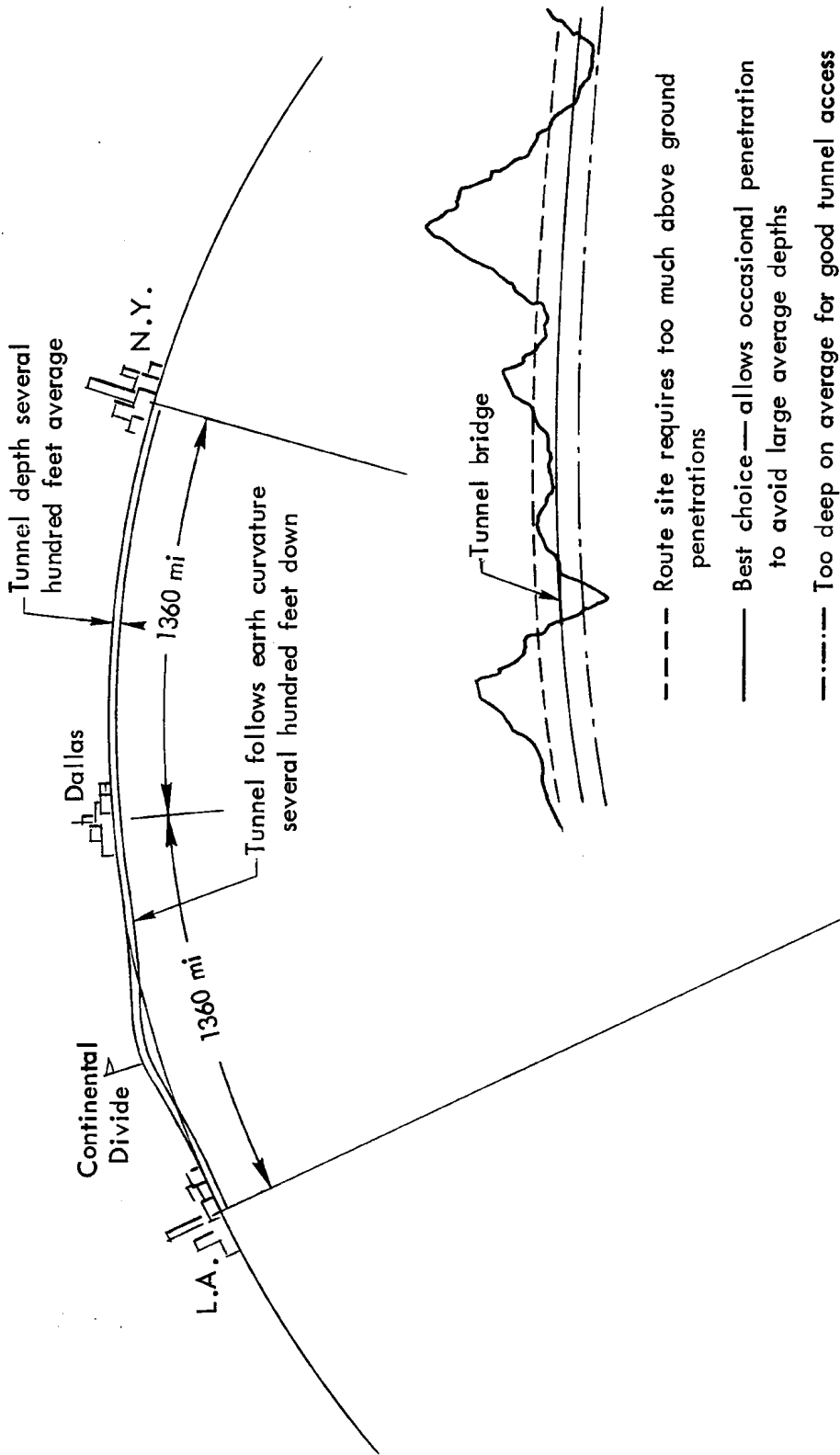


Fig. 10— Planetran tunnel route plan

How does an undertaking of this magnitude compare with other world projects? About 8000 miles of tunnels were drilled in the 60's in the free world alone and in our present decade this number will more than double. Italy itself has over 1000 miles of freeway with numerous large tunnels. As for under-ocean projects, a tunnel under the English Channel was considered at the time of Napoleon but only recently is active planning underway. The Japanese are about halfway under the Hokkaido Strait with a quite deep tunnel of 13.5 miles. Offshore oil wells have been drilled to a depth of several miles. The deepest well (Oklahoma) is 5.6 miles.

Such tunnel projects together with mines, storage caverns,^{*} pipe lines, and power conduit are all mutually supporting in the development of both undergrounding technologies and the needed methods for geological survey. Present day tunneling techniques will soon be greatly enhanced by more mature system-engineered procedures backed up with advanced tunnel-boring machines, water jet drills, hypersonic projectile spallation, laser and particle beam devices, and the Los Alamos "Subterrene" heated tungsten probe that literally melts its way through hard igneous rocks (Figure 11).

Technical Features

Other significant development challenges besides tunneling face Planetran. Prominent is the lateral acceleration problem. At speeds of several thousand mph, cars must maintain a very precise course to avoid excessive sideways forces on the passengers. At the maximum speed considered bending radii must be larger than 500 miles. Since Planetran's "tracks" are magnetic fields, exacting control of the fields themselves is necessary. Required is accurate "shimming" of electromagnetic power by minute, computer-determined vernier currents (Figure 12).

^{*} A significant macroengineering project can be found in the Pacer concept for thermonuclear production of electrical power and U^{233} fuel in 200 meter diameter steam-filled salt cavities one mile underground.

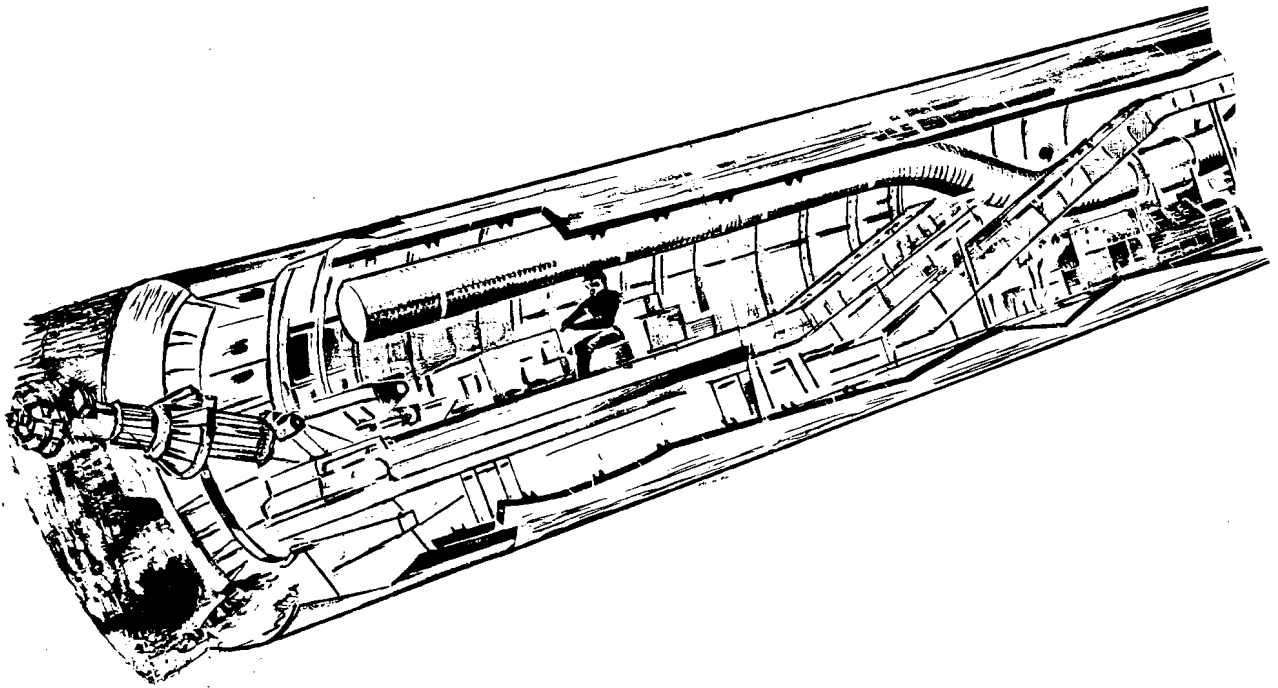


Fig. 11—Tunnel borer

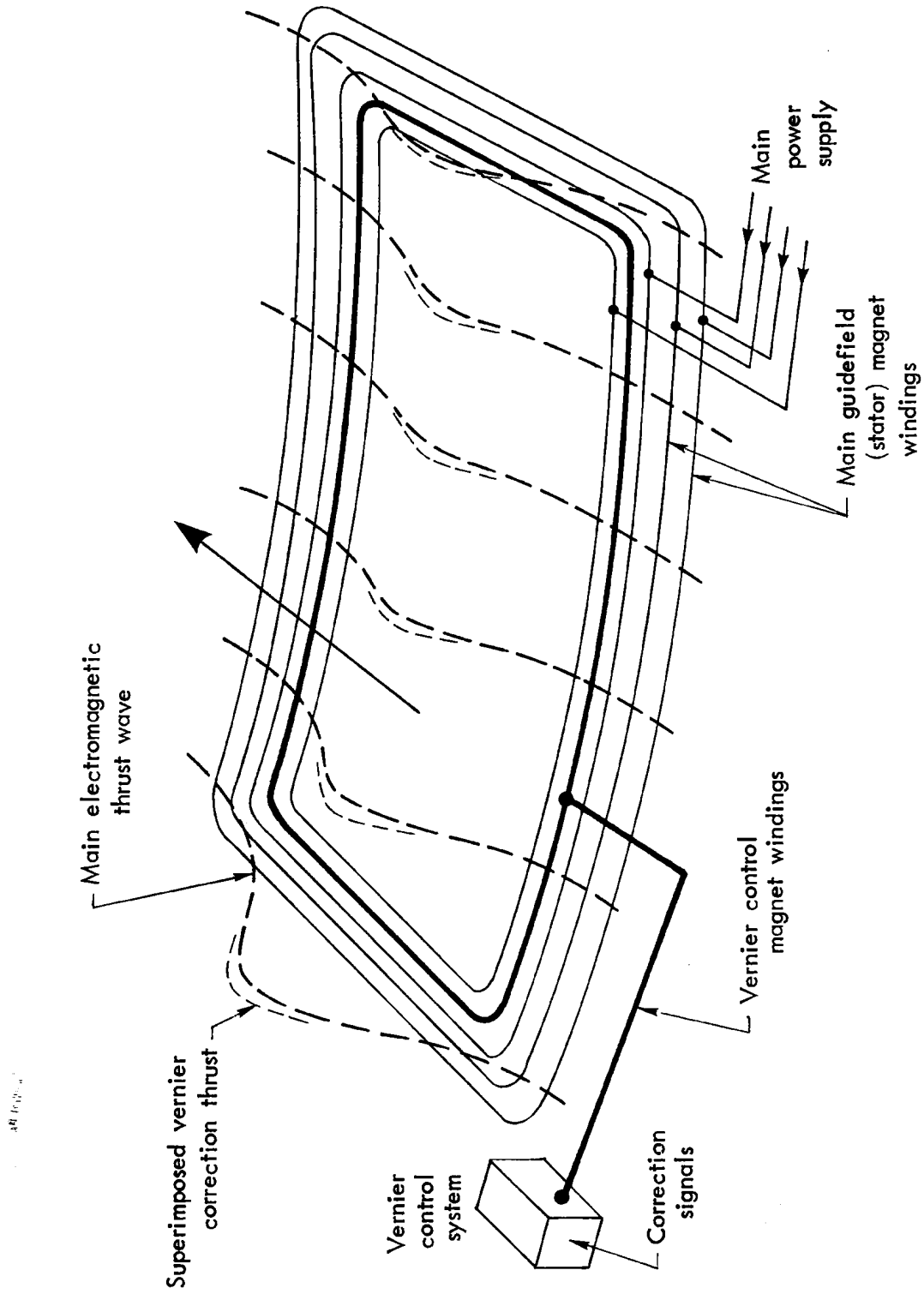


Fig. 12—Magnet shimming

Recent progress in compact, reliable, and low-cost microcomputers paves the way for such system control. Hundreds of these computers are distributed along Planetran's electrical guideway structure. Periodically emplaced detectors sense any tiny departures from the vehicle's specified course and acceleration schedule. These excursions are signaled on ahead to downstream control devices. Each downstream computer station has a set of read-only-memories (ROM's) containing "look-up" tables for optimally correcting microcurrents for the particular excursions sensed (Figure 13).

This same control system also keeps the magnetic guidefield in a fixed position in space even if the tunnel moves due to earth tremors. Inertial detectors mounted on magnet support structures supply signals that properly bias computer baseline data to account for such tunnel movements (Figure 14). The evacuated tube is supplied with a system of rollers, servos, and compliant joints to "ride with the punch" in the event of major earth shocks (Figure 15).

In order to minimize lateral acceleration, it is necessary to make the tunnels as straight as possible. This requirement in turn affects route choice for best tunnel construction conditions. Proper Planetran siting will involve detailed computer analyses of terrain contours and geological formations. These surveys along with Planetran tunnel excavation will greatly contribute to a national inventory of subsurface resources.

Planetran is a highly energy-conservative system. Cars contain cryogenically-cooled supermagnets for levitation. Travelling electromagnetic waves in Planetran's guideways (or "tracks") oppose the magnetic fields of the cars in a way that provides both support and forward (or reverse) thrust. For every car that's being accelerated in one direction, there's one in an adjoining tube going in the other direction that's being decelerated. Cars being decelerated return electrical energy to the system (just as was done in trolley cars of the past). And this energy transfer flow is confined to a local region.

Previously we noted that Planetran must be very precisely controlled -- every point in the system has its exact set of conditions that each passing car is expected to meet. This makes it possible to highly tailor

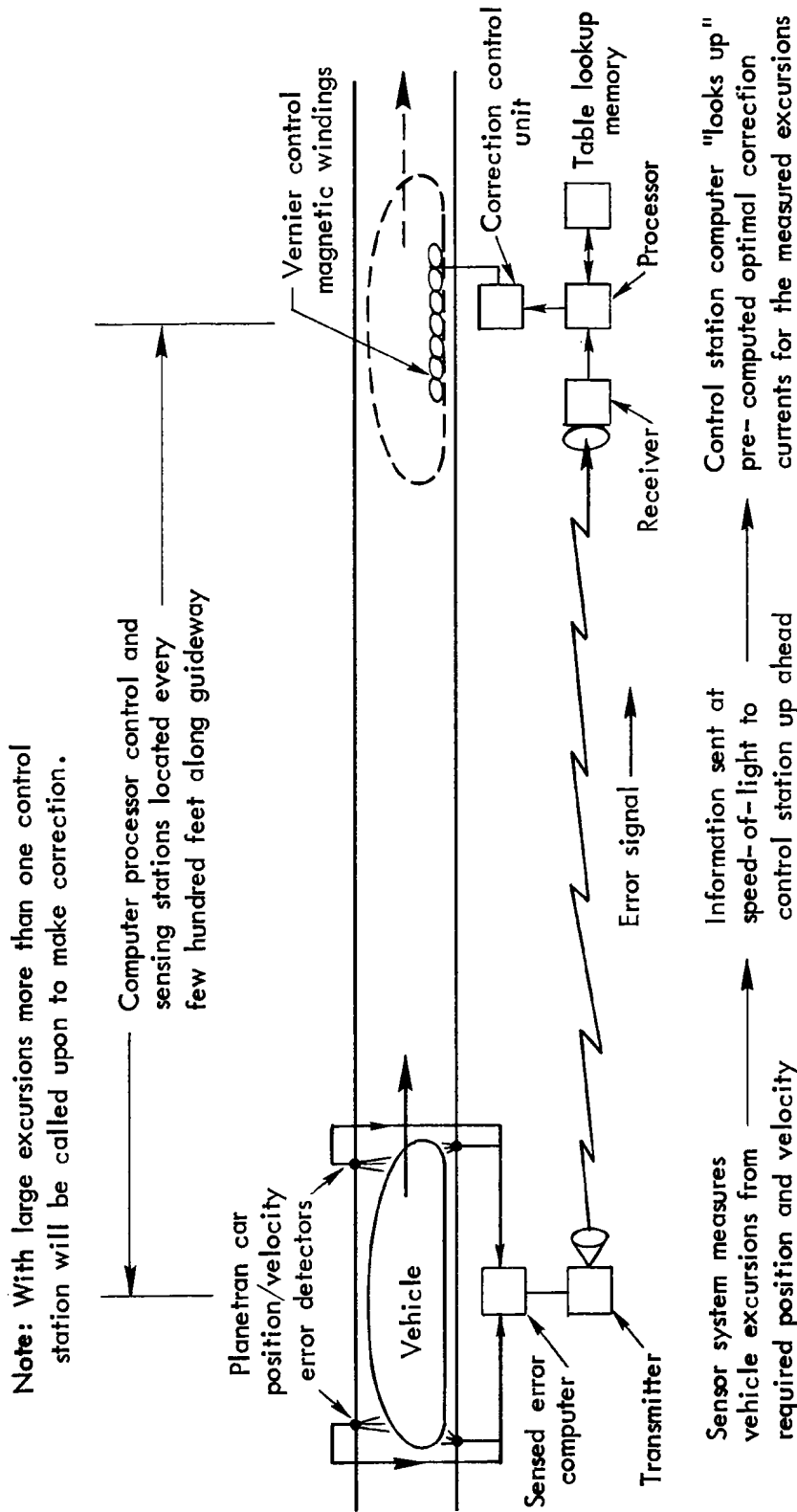


Fig. 13— Planetran sensor and microprocessor control system

Note: Inertial detector system superimposes its correction signals on same vernier windings/velocity correction system.

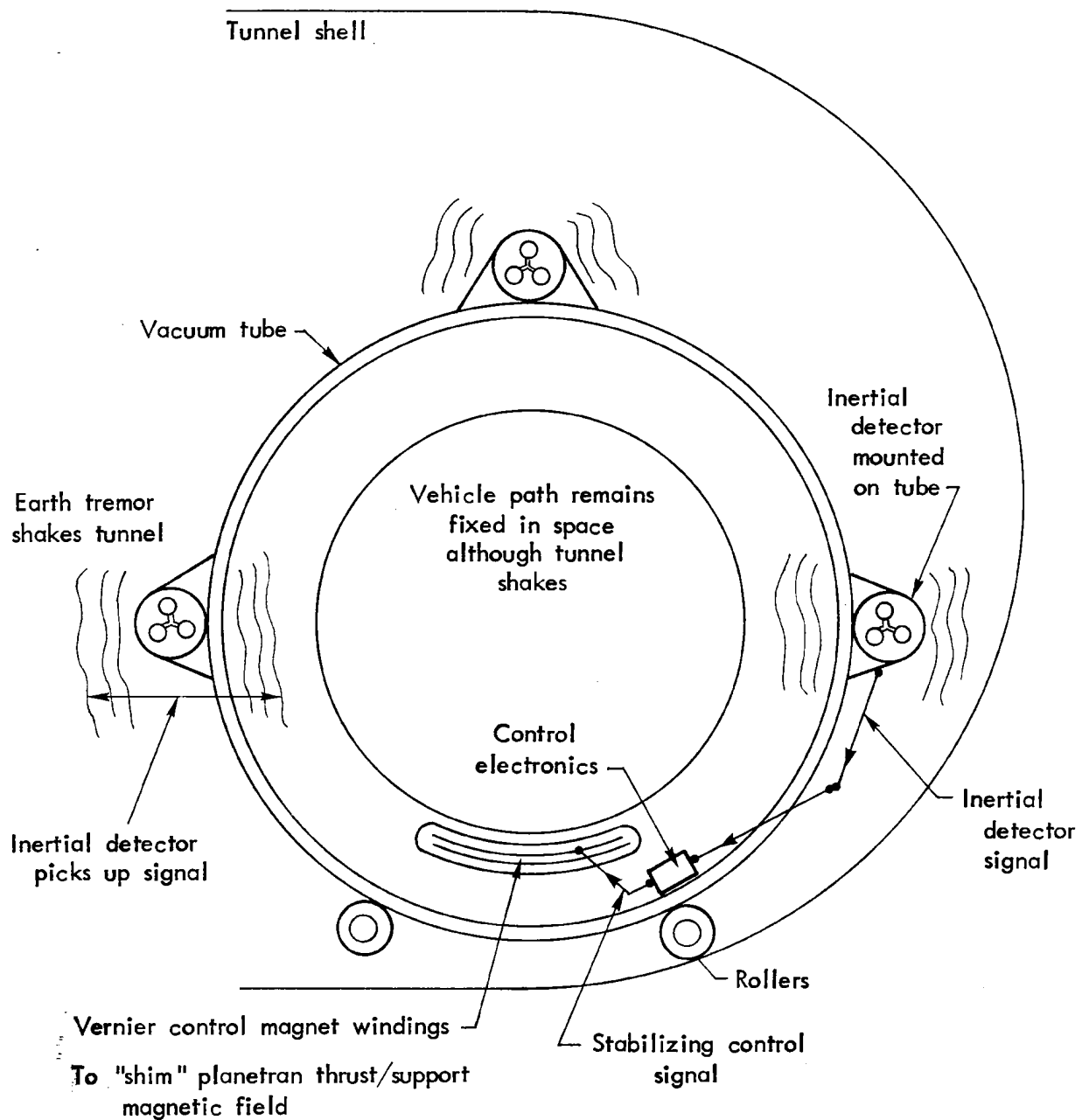


Fig. 14—Inertial detector system

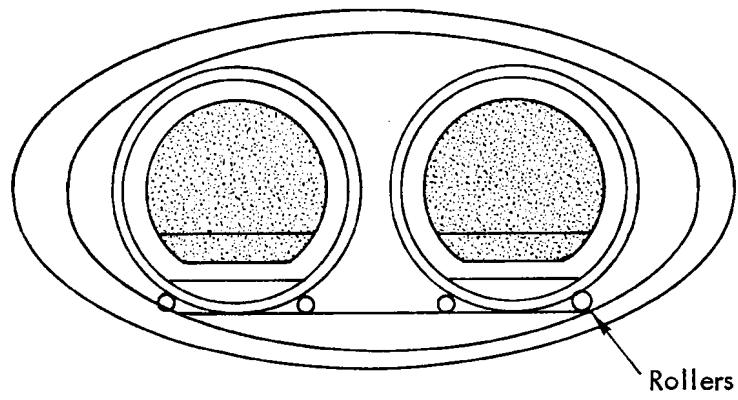


Fig. 15— Earth Tremor Roller Servo System

electrical systems at each point. Analogous large synchronous generators have losses less than 2%. We should be able to approach this efficiency with Planetran propulsion particularly since the "armature" uses superconducting elements.

Guideway stator fields can be supplied either by a triggered pulse forming network (PFN) in a linear accelerator or by continuously oscillating travelling waves from an alternating current supply as in a linear induction motor. The first choice has less electrical loss while the second option has less-expensive hardware. We have assumed the second type of system because it has greater flexibility for multi-car trains and also is probably more reliable.

Cars travel in a reduced atmosphere of 0.1% of sea level pressure (equivalent to about 170,000 ft altitude). This level of vacuum is not difficult to achieve requiring only "roughing pumps." Large fusion power reactors and particle accelerators have internal densities less than one-billionth of Planetran's atmosphere. Drag losses are negligible. Total cost of vacuum systems (based on two 2600 cfm roughing pumps per mile) for all links given in Figure 5, is estimated at \$320 million. Electrical power to operate the vacuum system is of the order of losses incurred in powering Planetran cars.

Planetran cars are much more efficient than aircraft. Not only are drag losses small and kinetic energy recovered, but Planetran also does not have to supply potential energy to climb to altitude as does an airplane.

It is estimated that Planetran will use only a few percent as much energy per passenger mile as an airplane. Coast-to-coast energy costs are less than \$1.00 per passenger.

Pre-stressed high-strength concrete is assumed both for the tube's vacuum shell and for tunnel lining based on Rand studies of 10,000 psi concrete for defense purposes, using irradiated distributed polymers. Scaling up costs of pre-stressed concrete pipe conduits for the Feather River Water Project yields \$63 billion for 21,000 miles of vacuum shell. Such concrete is dense enough for vacuum purposes, but a plastic or glaze wall coating is added for contingency. Joints are simple sleeve clamps over O-ring type packing with some allowance for cocking of one tube section relative to the next for alignment changes.

We have touched on only a few of Planetran's features and development requirements. Provisions must be made for emergency system stopping, fail-safe overall designs in operational and car life-support apparatus, quick-opening computer-controlled gates (valves) at tube ends, terminal car-handling networks, tube vacuum pumping and sealing, control system diagnostics, overall system maintenance -- and others.

Figure 16 illustrates concepts for a couple of these items. One scheme is a multiple vacuum lock system at tunnel ends for entering (or emerging) vehicles. Giant guillotine doors necessarily seal the Planetran train in locks of ever decreasing (or increasing) pressure served by high speed roughing pumps to reestablish proper vacuum conditions between Planetran passages. The doors are started in motion before the vehicle's arrival to minimize opening time.

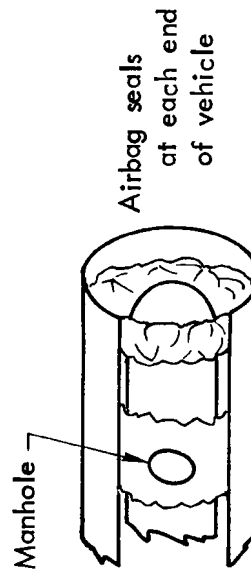
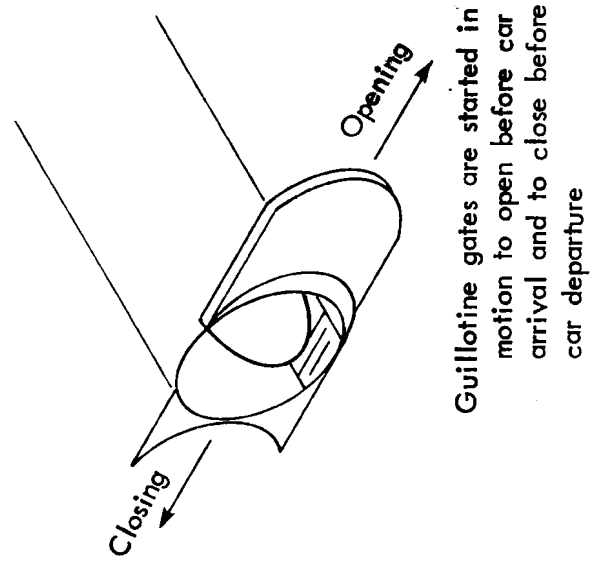
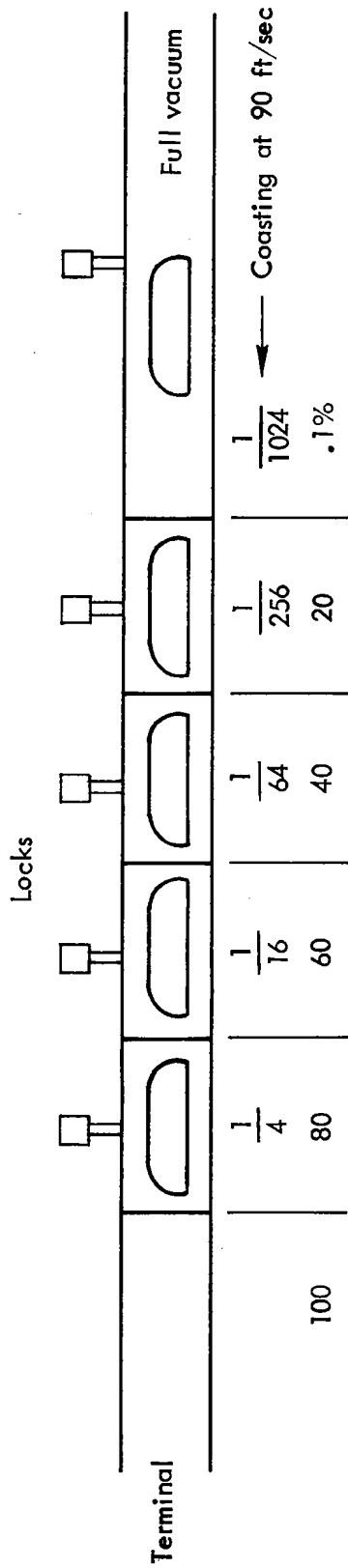
Airbag-like attachments at either end of a Planetran car partially inflate in the vacuum tube region to reduce longitudinal airflow. These same bags, fully inflated, also would serve to seal off a portion of the tube in the advent of an emergency stop for the vehicle. Periodically placed hatches in the tube wall permit passenger emergency exit from vehicle and tube.

Planetran does not require scientific breakthroughs or even new technology. Benefits derive from conventional electrical machinery systems, many of which are now being upgraded with superconducting components, and from new programs such as fusion power, scientific particle accelerators, and MAGLEV local transit systems. We have also discussed comparable fallouts in the tunneling field.

Planetran will follow reliability design concepts of the Apollo program as a highly successful, high-technology enterprise. We will also profit from the mistakes of some recent high-speed transit systems which attempted to directly harness modern sophisticated computer controls to 1890 braking systems without benefit of proper system engineering.

Economics

The U.S. Planetran system assumed for *discussion* and shown in Figure 5, has three types of central corridor links and feeder lines. In-tube Planetran trip times total 54 minutes for the one-stop Los Angeles-New



Partially inflated to aid in vacuum lock

Fully inflated for emergency stop
(Periodically placed manholes in tube wall)

Fig. 16 — Safety systems

York link, 96 and 155 minutes, respectively, for the nonstop and local portions of the 4-tube tunnels and 151 minutes for the 2-tube feeder lines. The overall total is 456 minutes. With 200-passenger (or *Planetran freight equivalent*) cars going both directions on one-minute headways and an assumed \$1 *per minute* fare, revenues of \$182,400 per minute or \$96 billion per year are computed for Planetran. Since energy costs are one percent or so nearly all of this revenue can be applied to amortized investment cost. Even at today's ambitious 20% yearly capital charges, this permits a system cost of nearly \$500 billion (for the Planetran portion alone, while our estimate of actual cost of the high-speed part is \$250 billion including \$185 billion for tunnels, terminals, and evacuated tubes).^{*} Transcontinental fares are \$54 or priority freight rates are 15¢/ton-mile (40¢/ton-mile on the shorter links).

Estimates of tunneling and construction energy requirements indicate that they represent less than \$1 billion of the overall system cost. Because of Planetran's efficiency, it probably saves this much in energy cost in just one year of operation.

The above example was prepared to show that with the combination of fast transit times, terminal convenience, and efficient energy utilization, it is possible to project relatively low fares. The question of whether sufficient passenger *and tube-freight* volume will occur under these favorable conditions is a question for future determination.

The combined passenger volume of present air traffic and long-distance auto travel approaches within a decade of the above Planetran traffic assumptions. Accounting for freight and growth in future demand could help bridge this gap, particularly with the inherent service conveniences offered.

Indeed, with short transit times it is possible for a businessman in New York to travel to Los Angeles during his lunch hour and hold an afternoon/morning meeting and return at his regular quitting time. His desire to do this would be greatly enhanced if Planetran went to 500-passenger trains and ten-second headways -- increasing volume 15-fold and permitting coast-to-coast fare reductions to perhaps \$6.

^{*} Of the \$65 billion cost of system hardware, \$6.3 billion is for Underground Power Generation and Distribution, based upon a Ralph M. Parsons Co. estimate for Planetran.

Even if fares were inadequate to cover Planetran's investment, it is still considered a worthwhile pursuit from a national resource standpoint -- both for defense and for socioeconomic reasons. Yet further is the prospect for sharing Planetran's tunnel costs with other underground system users.

Environmental Benefits

Transportation systems pose well known problems to the environment. The bitter controversy over the sonic booms of the Concorde has perhaps obscured some other environmental effects of the SST -- and aircraft in general. None of the energy required to levitate and propel the aircraft is recoverable; it all goes into the atmosphere along with combustion products. Long-term buildup of these products in the upper atmosphere is a matter of concern, and is a process that we are just beginning to understand. As aircraft become faster, airports must become more remote and operating altitudes higher, both aspects contributing further to environmental problems.

The use of a Planetran would alleviate these hazards to the environment; aesthetic considerations, advantageous relocation of utilities, and protection against sabotage would also suggest the desirability of underground placement of these systems. Right-of-way costs, surface congestion, grade separation problems, and noise pollution would be eliminated.

Sharing of facilities could help pay the high cost of such tunnels. Included among these contemplated underground systems are pipelines for oil, water, gas, waste disposal, and slurries of materials such as coal and other bulk commodities; communication links, including fiber optic channels for lasers and microwave waveguides; electrical power transmission lines such as superconducting cables; and passenger and freight-hauling systems.

Superconducting power cables will require a controlled environment to protect the cryogenic refrigeration system that makes superconduction feasible. A controlled-access tunnel is a virtual necessity for such a system. This type of power cable may alleviate many of the problems of siting of future power stations, since they can be located at great distances from the user and yet suffer negligible power losses in

transmission. Nuclear reactors, for example, could be located in colder regions and the thermal effects of their cooling effluent employed in such useful ways as to enhance growth in fish "farms."

Laser communication channels along with "repeater" stations will most certainly require the protection of an enclosed channel. Future video-phone services will require millions of wide-band links. Even though present fiber-optic laser links can carry up to fifty two-way video channels on a hair-sized filament, we might still need 100,000 of these links. Along with signal boosters this system could itself occupy much of a tunnel.

A Companion Rail Transport System

The development of a routeway for a Planetran system offers the potential for the collocation of an advanced Fast Rail System (FRS). FRS is designed to interface with existing railroads and to carry semi-trailers, container cargo, campers, and items too bulky to fit the configuration of Planetran cars. Its tunnel is collocated with Planetran tunnels and shares power and service installations.

The FRS consists of a transcontinental link plus potential substitutions in 4-tube links. Computer-controlled trains travel on rails at 100 mph and are electrically driven. Rail travel within Planetran tunnels offers conditions of negligible curvature, minor grades, and no side winds or other weather problems. Our original concept was to place standard rail cars within self-powered, highly-streamlined gondolas with steel wheels-on-rail support. However, we have found that a conventional rail system utilizing Planetran's benign tunnel conditions may be the best choice. One critical problem is reliability of wheel bearings, particularly with the older journal variety. Examination is needed of costs incurred in potential lost track availability versus those for retrofitting existing wheel systems (versus going to dollies or complete gondolas for rail car transport). We could, for instance, simply limit FRS to "roller freight" cars.

A highly streamlined train at 100 mph requires 100 hp per car, about equally divided between rolling and air friction. Three hundred hp per car will permit use of un-streamlined cars and provide for 1/2 percent

grade climbing (at somewhat reduced speed). Electrical energy costs of perhaps 0.3¢/ton-mile compared to 0.2¢ for streamlining suggest that additions of fairings to cars or enclosing them in gondolas may not be cost-effective -- particularly when considering gondola-insertion costs at marshalling yards.

To accelerate to 100 mph in a reasonable distance requires yet more horsepower. However, gravity can be used in bringing cars up to speed from the marshalling yards and decelerating them upon return; a drop of about 300 ft is needed for the acceleration considered.

FRS trains are assembled at marshalling yards contiguous to an FRS/Planetran on/off ramp. Trains are accelerated to tube speed and phased into a train in the tube under computer control. Train segments are interconnected in the tunnel to form trains of length sufficient to reduce air resistance. Tunnel trains can be reformed with only slight speed changes to isolate a slot to add or discharge cars to or from the system. Input/output maneuvers are performed at any point where the roadway altitude is compatible with surrounding territory, making FRS available to cities and areas where no Planetran terminals exist.

Trains are closely spaced and under phase-locked control. Coast-to-coast takes about a day in transit, obviating the need for transcontinental trucking and reducing many air-freight requirements. It would be a boon to container shipping, offering the long-sought "land bridge" coast-to-coast link, carrying 7 million tons/day. FRS should substantially revitalize U.S. rail freight lines.

System Development

Development of a system like Planetran is a prodigious undertaking. By its very nature, it will be difficult to reap Planetran's benefits in piecemeal stages. Until main corridor links are operating, its high-speed nature cannot be exploited; and even with these links, the feeder link infrastructure and local transit interfaces must be established to realize Planetran's full social and economic potentials.

Our latest move toward multiple-use tunnels will help establish Planetran -- shortening the gap between system development and initial revenues. By building the tunnels first for other purposes we can

improve the odds for achieving Planetran in a finite time. Early rail and utility revenues will not only help defray tunnel costs but will also contribute to initial Planetran funding.

Another benefit with this approach is that the tunnel program could be conducted under the aegis of the Armed Services and various Civil Preparedness agencies. Military uses of such a tunnel network for dispersal of command centers or strategic missile launchers, and for protected strategic communication and sensing links have been studied for many years. Civil Defense shelter and underground industrial deployment plus Planetran/FRS transportation features will enhance U.S. Defense posture. It should be noted that 30 years ago when the U.S. RDB (Research and Development Board) was pondering space development, it was decided that military pursuit was necessary in initial space R&D stages; that we otherwise would never achieve space on the basis of scientific or commercial sponsorship.

A strong analogy exists for Planetran.

The metamorphosis of a Planetran tube is shown in Figure 17. A two-way set of railway tracks is initially used in the tunnel building process to haul away "spoil" and bring in equipment and tunnel lining structures. These tracks are then employed first for military uses. Later, various levels of FRS fast freight service are established. Utility pipelines and cableways can also then be incorporated.

In these early phases of tunnel building, followed by the institution of FRS and upgrading of the U.S. railroad system, there will be a high employment opportunity for both skilled and unskilled labor for perhaps a decade or more.

At such time as the Planetran high-speed system development is initiated (perhaps as a multi-company venture), FRS can be employed to bring in vacuum tube shell segments and electrical and vacuum systems hardware.

We previously noted that one or both of the local Planetran tubes of a 4-tube tunnel could be replaced by FRS rails (but these could not accommodate some of the larger railroad car sizes now being employed). We can consider alternate two-way service on a single rail link, but probably not in a Planetran tube. Figure 18 illustrates how we might

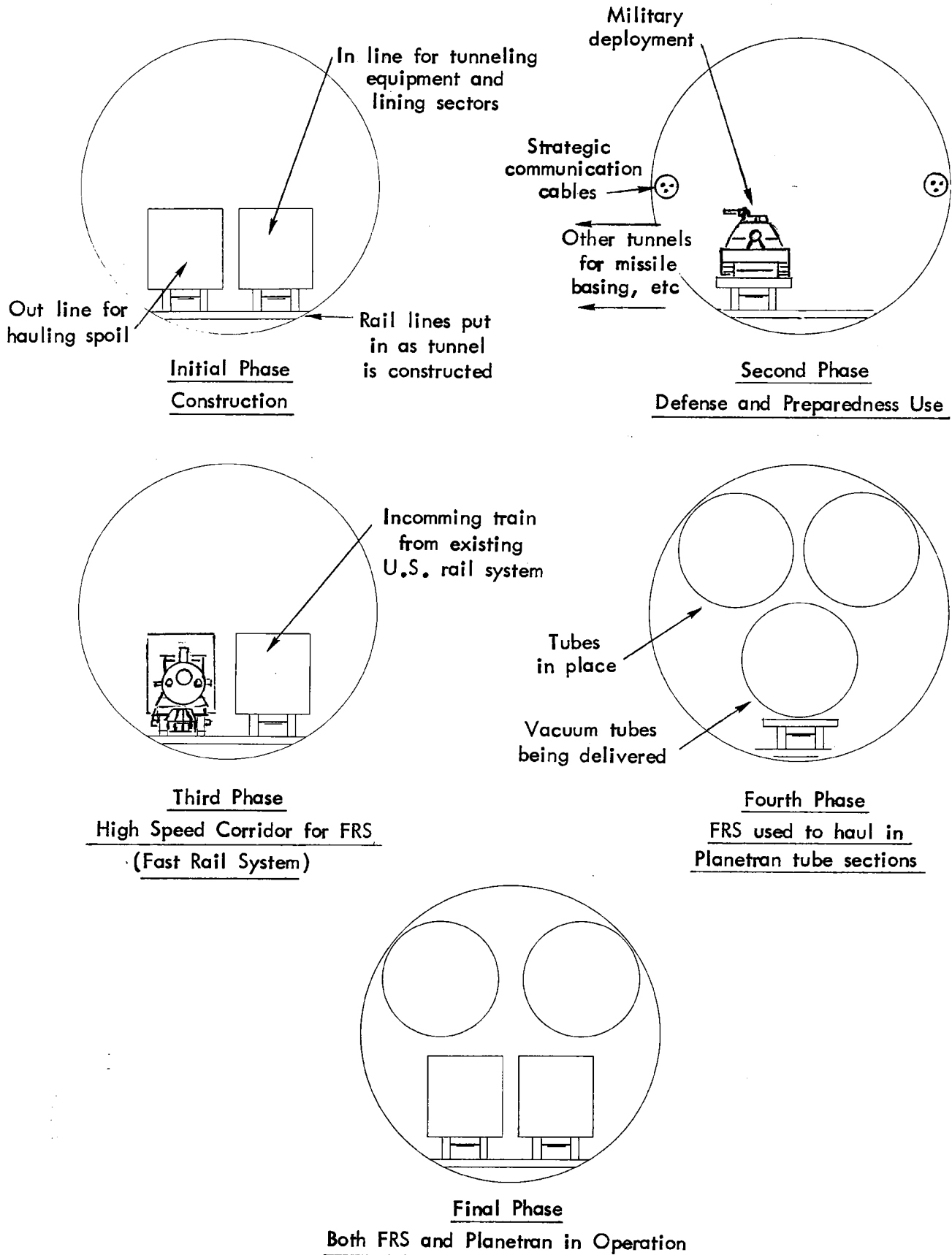


Fig. 17— Phased utilization of Planetran tunnel

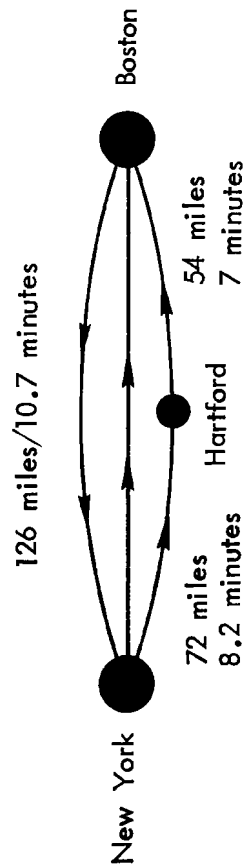
rearrange the New York to Boston four-tube tunnel. By using only one local tube going via Hartford, we confine the local service to one direction -- say North. (However, two-way service is still quite fast as shown in Figure 18.) Even though one must go from Hartford to New York via Boston, the total transit time is still only 18 minutes. The other local Planetran tube is replaced by an FRS rail system that operates in opposite directions, changing every 75 minutes. The phasing of this is also illustrated in Figure 18.

Building in such capability will greatly assist flexible response to local transportation needs with a system that is by its very nature highly inflexible. We may find that there is a greater need for rail traffic than high-speed tube links in some regions and thus need for allocating both local Planetran tubes to FRS. The region may involve considerable dispersion of urban areas for which motor vehicles provide the essential transportation services. It may be appropriate, for example, to have extensive auto-rail transport to augment such an area.

This reemphasizes the situation previously mentioned that autos have been performing all but 10% of U.S. *intercity* transportation for the last 30 years. We should not spend time trying to vastly replace this mode with local rapid transit but instead should focus on augmenting this modern-day phenomenon. The only part of AMTRAK that has derived more than an indifferent public response has been the auto/train which was immediately booked completely.

In many areas the auto has become a way of life -- look at vans, for instance. Also a way of business. We must be prepared for the Los Angeles salesman with a car trunk full of shoes who wishes to display his wares in Fresno. With FRS/Planetran he can put his car on FRS at a scheduled time of 2-1/4 hours and himself take the local Planetran tube up in 15 minutes -- this in place of a present 4+ hours each way by freeway. While waiting for his car he can have breakfast, telephone, or shop -- shopping centers will find a bonanza at Planetran terminals.

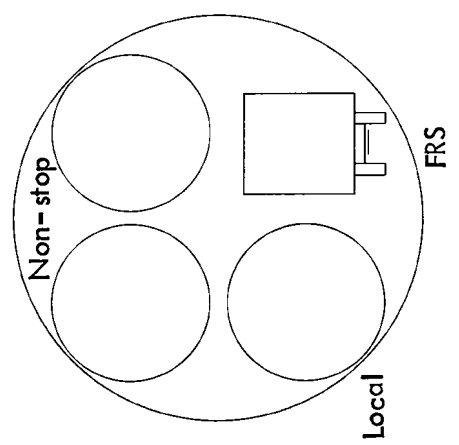
People traveling to Fresno with a motor home may prefer to spend the two hours relaxing aboard FRS in their own vehicle prior to their subsequent drive into the Sierras.



Combined non-stop and one-way service

Route	Transit time (minutes)	
	Planetron	FRS
New York to/from Boston	10.7	
N.Y. to Boston (Hartford stop)*	15.2	75 (to 150)*
New York to Hartford	8.2	
Hartford to New York	17.7	43 (to 118)
Hartford to Boston	7.0	
Boston to Hartford	18.9	32 (to 107)

* FRS transit time New York to Boston is 75 minutes but maximum wait for direction change is also 75 minutes hence maximum time New York to Boston is 150 minutes



Direction change cycle for FRS

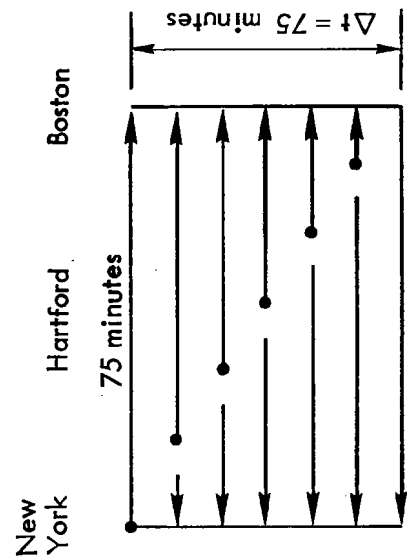


Fig. 18— Adapting to one-way local Planetron service

I have perhaps dwelt excessively on these examples, but I feel very strongly that we must develop systems that are useful to the public -- otherwise they will dwindle on the vine as did the railroad passenger business.

It is far more important to determine *what we need* in the way of transportation systems of the future, than *how we are to do it*. The present status of our technology allows us to do fantastic things -- the hard part is in defining requirements.

Future Prospects

We have noted that Planetran offers safe and highly convenient transportation service with low energy cost and minimum environmental impact. Other environmental benefits seen are those accruing from collocation of utilities and companion rail systems in Planetran's tunnels.

The technical problems associated with the Planetran development are manifold and difficult -- but no scientific breakthroughs are required. Critical areas include tunnel alignment, vehicle lateral acceleration, vehicle control and damping, and the tunneling process itself. Technology needed for these and other development areas of Planetran already exists. We have only the requirement to do the system design that incorporates this knowhow.

Will such a system ever be developed? It should be said that the political outlook is much less optimistic than the technical one. For one thing there is no jurisprudence bearing on the freedom of underground movement akin to that for the skies and the high seas. History has shown that some obvious projects, such as tunneling under the English Channel proposed in the time of Napoleon, can be delayed for centuries because of political pressures. On the other hand, relatively primitive societies were able to achieve such engineering feats as the pyramids with a much larger proportional bite out of their gross national product than is posed by Planetran on our present GNP of \$1.7 trillion. One interesting aspect that may be politically appealing is that Planetran's tunneling job can be done many places simultaneously, utilizing local community resources.

There is the problem of considerable financial outlay prior to reaping Planetran's benefits which we hope to partially alleviate by military tunnel sponsorship and by early rail and utility user revenues. It is interesting to speculate on the prospects for automobile development when Henry Ford started building them had it been necessary at that time to fund the present \$400 billion U.S. freeway system.

Are there compelling reasons for Planetran? The answer to this is an emphatic yes!! We no longer can afford to continue to pollute our skies with heat, chemicals, and noise, nor to carve up our wilderness areas and arable land for new surface routes. Nor can we continue our extravagant waste of limited fossil fuels. We need to get the bulk of truck traffic off highways and free these routes of much of the commuter auto traffic in order to restore to motorists the pleasure and convenience of driving through the countryside.

Is the Planetran really far-fetched? In order to gain proper perspective, it is instructive to look back over the last 100 years in transportation and see how far we've come.

Present travel and freight systems have proliferated without much attention given to their inter-relationships or integrated plans for the future. Without inspiration for future betterment we could have just "more of the same" in 2078. A concerted effort is needed to at least look at where we're headed. Planetran may prove not to be a viable part of future transportation, but we should at least understand that which is needed. We need to know not only the promising transportation methods but also their potential impact on future growth patterns and socio-economic development.

The U.S. has the greatest industrial and technical basis in world history. We proved that we could perform the prodigious feat of placing man on the moon. It would be useful to employ a small fraction of that capability to explore our future options in travel on this planet.

RAND/6092

TRANS-PLANETARY SUBWAY SYSTEMS -- A BURGEONING CAPABILITY

Salter